History of the discovery of the radio

To the 150th anniversary of A. S. Popov

V. Merkulov

> *We made a discovery, the meaning of which hardly anyone will immediately understand.*
>
> ***A. S. Popov, 1895***

March 16 (4), 2009 marks the 150th anniversary of the birth of Alexander Stepanovich Popov, the discoverer of the radio. The published article describes the immediate background and embodiment of a physical phenomenon called "radio" in the 20th century. Many scientists were on the verge of discovery, but our compatriot still recognized the priority.

"Abstract" creations of the future

A.S. Popov 1896

Fast and invisible electromagnetic oscillations (EMC) were studied by many physicists in European countries and the United States even before the English theoretical physicist J. Maxwell (1831-1879) published his famous work "The Dynamic Theory of an Electromagnetic Field" (1864) and "A Treatise on Electricity and Magnetism" (1873). So, for example, the American physicist J. Henry (1797-1878) in his work "Vibrational discharge" published in 1842 [1, p. 243-245] showed the existence in the Leyden bank of "the main discharge in one direction, and then several reflected actions back and forth, each of which is weaker than the previous one, continuing until equilibrium is reached"; that "the discharge of the Leyden battery through the conductor creates an induced current in the adjacent parallel conductor." In addition, the spark is "about one inch long (25,

Leading German physicist and physiologist G. von Helmholtz (1821-1894) in 1847 in the article "On the Preservation of Strength" [1, p. 246] also explained that "the discharge current consists of alternating, oppositely directed currents." In 1858, the Austrian professor of physics P. Blazerna (1836-1918) presented the results of studies on measuring the current value in a secondary ("side") wire, stretched parallel to the wire closing the Leyden battery, in a paper published in Vienna on Induced Secondary Battery Current "[1, p. 258-263]. He stated in it: "With the same main wire, the induced current for side wires of different lengths will not be constant, but increases to a certain maximum limit, and then decreases again." He showed graphically changes in the voltage value in the secondary circuit [1, p. 261] in the form of a very smooth curve

In the years 1857-1862. the prominent German physicist V. Feddersen (1832-1918) measured the period of oscillations during discharge discharged into groups of Leyden cans loaded with wires of various lengths. In 1862, in the work "On the Electric Discharge of a Leiden Can" published in the "Annals of Physics" of the Prussian Academy of Sciences [1, p. 275-285] he reported the receipt of values in the range from 1.32 to 39.8 μs with the length of the closing circuits from 5.26 to 1343 m, respectively.

The listed works only explain that the great German physicist G. R. Herz (1857-1894) did not open EMCs that were invisible to the eye not from scratch. There is no reason to believe that he was visited by a sudden "insight". The significance of his work lies in the fact that he was the first to give an interpretation of the phenomena that seemed to many to be in the form of vague images. Continuing Maxwell's theory and terminology, he was the first to formulate the concept of "electrodynamic wave" [1, p. 156-165]. In a significant part of the research, Hertz revealed differences between EMC and light, studied their features: like light, they propagate with the same speed in vacuum and air; unlike light, they penetrate through wooden and stone obstacles, fog, but do not move in the ground and water; do not go inside even the thinnest metal barriers, but only reflect from them.

Hertz proposed a real and reliably working receiving-transmitting system (PPS), repeated by many experimental physicists. In the transmitter, the antenna was the dipole he invented; in the receiver, a tunable circuit. However, the length of the spark Hertz had to measure "by eye", using measuring rulers and magnifying magnifiers.

Immediately after the Hertz experiments, many came up with proposals for using faculty for wireless telegraph signal transmissions. However, he himself did not understand the significance of the discovery. Information on high-frequency EMC, as well as Maxwell's electrodynamic postulates, he attributed to abstract knowledge, and not to real life. So he spoke at lectures in an educational institution and answered questions of students. In 1889, he wrote to a German engineer F. Huber that to transfer oscillations used in telegraphy or telephony, for example, 1000 units per second, it would be necessary to construct unrealistic circuits 300 km in technical devices [1, p. 32].

Conductivity of powders

In the years 1884-1886. the Italian physicist F. Calceschi-Onesti (1853-1922) from the city of Lapedon investigated the conductivity of metal filings deposited on insulating plates of various shapes, as well as placed in cylindrical glass or ebonite tubes [1, p. 350-353]. The plate or tube was connected to the battery through a galvanometer indicating current. The galvanometer needle showed the passage of current when connected to the battery, after which it returned to the zero position due to the loss of conductivity by metal filings. Therefore, restoration of the initial state of the powder was required. Partial acceleration of the process helped reverse the polarity of the effects of the battery on the circuit. Sometimes, as a sound indicator of conductivity, Kalceski-Oneski used a telephone set parallel to the battery or in series with a galvanometer. He found out, that the phone instantly returns metal filings to a state of conductivity when the circuit breaks. Then he replaced the phone with an electromagnet, and then a matched inductor with a similar result. He concluded that the conductivity of metal filings changes due to the excitation of self-induction EMF in the inductive element of the circuit.

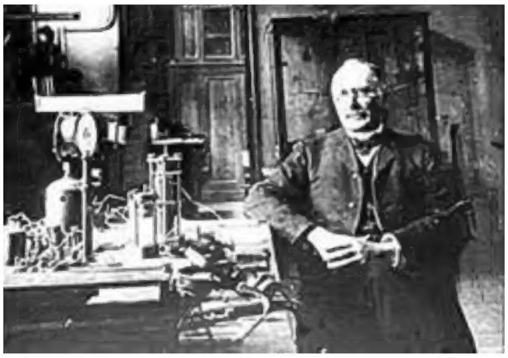

Fig. 1. Photo Branly in the laboratory

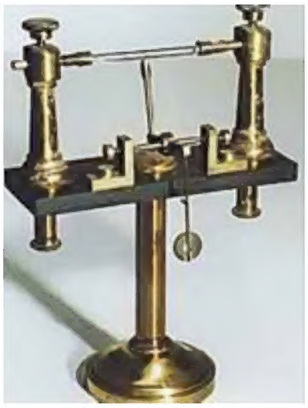

Fig. 2. Radio conductor

Studies of the conductivity of metal powders were continued in 1890 by the French professor of physics at the Catholic University of Paris, E. Branly (1844-1940). He repeated the experiments of Calcesky Onesti and confirmed his observations. Initially, he also applied thin layers of crushed copper, iron, aluminum and other metals on rectangular (7v2 cm) frosted glass plates. Later, metal filings, sometimes mixed with insulating liquids, he poured into glass or ebonite tubes with electrically conductive rods at the ends.

Branly placed the descriptions of the experiments and the generalized results of the research in the reports published in 1890 and 1894 [1, p. 353-357]. He said that "a negligible current initially flows in the circuit that combines the battery, galvanometer and ebonite tube with metal filings, but the resistance decreases sharply at the tube, which can be seen from the strong deflection of the galvanometer if one or more discharges are made near the circuit." "The action decreases with increasing distance, but it is very easy to observe, even without special precautions, even at a distance of more than 20 m, and the spark apparatus worked in a room separated by three large rooms." "For an action to take place, the circuit does not have to be closed." "The passage through a sensitive substance of an induced current produces the same effect, as a spark at a distance (the induced circuit contains an inductor, a tube with sawdust, a battery and a galvanometer). " "The reduction in resistance can almost be eliminated in various ways, especially with weak jerky hits on the plate supporting the tube."

Branly called the developed design of a glass tube with a metal filler a radio conductor (RK), i.e., a conductor of incoming radiation. The surviving photo of Branly in the laboratory is shown in Fig. 1, the radio conductor - in Fig. 2, a radio conductor in a circuit with a galvanometer and a battery - in fig. 3. In fig. 4 shows a diagram of electrical tests. In order to neutralize the shunting effect of the power battery on the radio conductor, Branly placed wire resistors with ordinary (turn to turn) windings on the frame, therefore having some inductance (Fig. 5). Some Branly researchers have taken them for elements of selection.

It was noted that the sensitivity of the radio conductor increases with lengthening of the wires connected to it. This feature was used when placing it in a shielding case (in order to protect it from unwanted interference). Sensitivity was restored by removing meter wires through an opening in the box. Branly fans later considered these wires to be antennas.

Branly was nominated three times for the Nobel Prize, but he never went to the laureates. In his native France, he is worshiped as a pioneer in the field of radio.

The first to fully evaluate Branly's research was the famous English physicist O. Lodge (1851-1940). He suggested using a tube with metal filings to detect high-frequency EMC - "Hertz waves". He wished to name the radio conductor as a coherer (from the English to cohere - to interlock), since even a weak current passes inside the tube, the particles "stick together" with each other. This term was first voiced in the public review lecture "Creation of Hertz" delivered at the Royal Institution of London in June 1894 and dedicated to the memory of G. Hertz, who died at the beginning of the year. He outlined the results achieved. Among other scientists, he noted the interest shown by the Russian physicist and electrical engineer A. G. Stoletov (1839-1896) in studying the effect of light effects on sparking in Hertz circuits. Lodge expressed the idea of including a telegraph key in the teaching staff of Hertz [1, p. 424-445]. In fig. 6 The lodge (sitting) is depicted in the laboratory with his assistant J. Bird (1888-1946) - the future "father" of electromechanical television.

Note that in the scientific and technical literature, the idea of wireless telegraphy was originally proposed in 1890 in the Russian journal Electricity as a commentary on an article by physics professor O. D. Khvolson (1852-1934) [1, p. 415]. In 1892, the famous English physicist and chemist V. Crookes (1832-1919), who himself did not deal with the transmission of code messages over the air, in one of the journals of the spiritual profile gave a surprisingly accurate clairvoyant description of wireless PPS [1, p. 416-420].

On August 14, 1894, Lodge spoke at the University of Oxford at a scientific session of the British Association for the Advancement of Scientific Achievements. At the meeting, he showed one of his designs of a tube (glass) coherer filled with iron filings mixed with mercury and oil (Fig. 7). He demonstrated EMC reception from a distance of 40 yards (37 m) from the Hertz oscillator (emitter) with a trembler signal (electric bell). The lodge did not think of using the vibration of the bell to shake the glass tube, i.e., bringing the coherer to its original state by the arrival of the next impulse. Surprisingly, according to the connection diagram (Fig. 8) on the desktop, the coherer and the bell

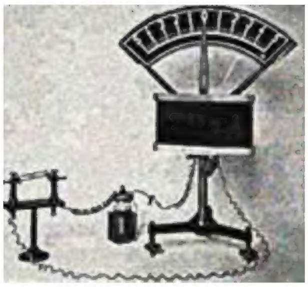

Fig. 3. A radio conductor in a circuit with a galvanometer and a battery

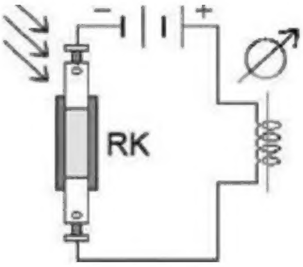

Fig. 4. Scheme of electrical tests

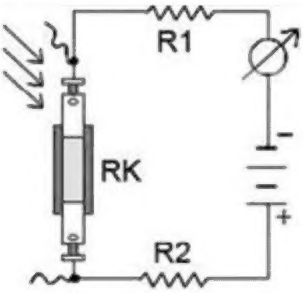

Fig. 5. Branley electrical test circuit

Fig. 6

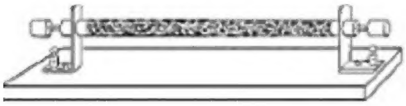

Fig. 7. The design of the tube (glass) coherer

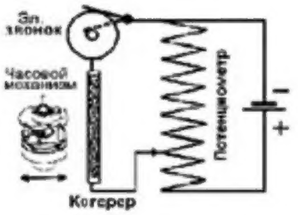

Fig. 8. Connection diagram

were placed nearby, but on different grounds. For mechanical action on the coherer, another "shaker" was added - the clockwork mechanism of rapid rotation,

A little later, the coherer and the electric bell were nevertheless combined on a common board, but still did not receive the effect of restoring the device's performance, so the mechanical "shaker" was retained. In addition, the Lodge receiving device did not have an antenna, and for an electric bell, a rather high current was required, so the device was not very sensitive.

The lodge was more a cabinet scientist than a practitioner. He did not see the future of telegraphy without wires, so he limited himself to creating laboratory models, as if connecting the experiments of Hertz and Branly. However, in the UK, the Lodge is recognized as one of the pioneers and pioneers of wireless telegraphy.

Hertz Waves in Russia

Professor of Physics at Moscow University A.G. Stoletov proceeded to repeat the Hertz experiments in 1888. He focused on conducting experiments "on the action of light rays on electric charges of weak potential", the descriptions of which were presented in the article "Actinoelectric studies" (1888) published in the Journal of the Russian Physicochemical Society. With a presentation of the methodology for conducting experiments and materials of the article, he spoke on December 30, 1889 at the Eighth Congress of Russian Naturalists and Doctors [2]. Again at the congress on January 2, 1890, Stoletov, in a speech entitled "Ether and Electricity", proclaimed "the beginning of a new era in the development of science", which came about thanks to the discovery by Maxwell and Hertz of fast electrical vibrations invisible to the eye.

Four days later, at the congress, professor of physics at the St. Petersburg Military Medical Academy N. G. Egorov (1849-1919) and his assistants "showed eight experiments performed by Hertz related to the detection of electromagnetic waves, the study of their properties and propagation conditions in the air." Before the congress, Egorov made his first demonstrations of Hertz's experiments and explanations to them back in April and May 1889.

During the congress, participants and guests visited the Mining Officer class in Kronstadt, where the physics and electrical engineering teacher A. S. Popov (1859-1906) showed the assembled installation to demonstrate Hertz's experiments in detecting "electromagnetic waves" in a physical room. In public, with a lecture "On electrical oscillations with a repetition of the experiments of Hertz," A. S. Popov spoke on March 22, 1890 at the Maritime Museum of the Main Admiralty of St. Petersburg [3, p. 47.48].

A. S. Popov was familiar with the work of the American electrical engineer N. Tesla (1856-1943). He "in February 1891, they reproduced and demonstrated Tesla transformers and experiments with them" [3, p. 48]. In 1893, Popov met with Tesla's antennas, while on a business trip to the United States at the Chicago World's Fair. In 1894, Popov repeated the experiments of Branly and Lodge. By the end of 1894, he had made a version of the Lodge receiving apparatus - a "radiometer" -thunderstorm detector with a vertical antenna. At the beginning of 1895, he demonstrated the device at a meeting of the physical department of the Russian Physicochemical Society (RFHO), in educational institutions and at lectures for a wide audience in St. Petersburg.

Day in history

On May 7 (April 25), 1895, at the next meeting of the RFHO, A. S. Popov made a historical report "On the relation of metal powders to electric vibrations" [3, p. 53, 54], where he made a report about "a device designed to show fast oscillations" connected to an external conductor, "located in their scope." He demonstrated the faculty in which the receiver automatically received EMCs emanating from the Hertz oscillator located in a neighboring building at a distance of 30 fathoms (64 m). The PPP transmitter was low-power, and it was obvious to A.S. Popov that it was still premature to attempt to establish telegraph communication with him. However, the receiving part was already quite sensitive for detecting EMC generated by powerful sources, for example, lightning discharges. The receiver caught them at a distance of 30 km.

For practical implementation, it was decided to convert the receiver into a light detector with the addition of a writing apparatus of the Richard brothers for automatic recording on paper tape. Recall that the first lightning detector was shown at an exhibition in Nizhny Novgorod in 1896, after which it worked for its purpose until 1927 at the Forest

Institute of St. Petersburg (now S. Kirov St. Petersburg State Forestry Academy). A. S. Popov also used the developed devices in the educational process as visual aids.

Scientific act

The significance of the initial and further works of A. S. Popov is very great. Although in laboratory research G. Hertz, E. Branly, Oh. The lodge was also offered technical solutions for their implementation; they turned out to be suitable only for spectacular demonstrations of the phenomena studied. At the same time, they were far from useful applicability to the mind-boggling telegraphy without wires. Scientists initially did not puzzle themselves with applied work completions. Over the years, Lodge, for example, recalled that he dealt with the coherer along the way in indicating EMC. It did not turn out that they completely swallowed it.

Abroad and in Russia, many repeated the experiments of these scientists and stopped there. No one else could do anything. The works of A. S. Popov proved the practical necessity of the "abstract" material accumulated by them. Using an example of a lightning detector, he showed the equivalence of EMC of artificial and natural origin. Note that at the end of the XIX century the problems of lightning protection seemed relevant to many. With two articles of the Lodge on lightning rods, which are considered specialists in depth in content, can be found in [1, p. 313-331].

By December 15, 1895, A.S. Popov had prepared a report on the research and development. The work entitled "A device for detecting and recording electrical vibrations" was published in the January issue of the Journal of RFHO for 1896, which had an international mailing list [1, p. 449-458]. In the article, A. S. Popov discloses the design and circuit solutions of the created devices. In the receiving part, he refused the clock mechanism proposed by Lodge. For the first time in the practice of electrical connections, he forced the main elements of the device to function in automatic feedback mode: the drummer of the electric bell cup on the way back (after being triggered by the incoming signal), returning to its original position, also hit the coherer case. A. S. Popov increased the sensitivity of the device, why, in series with the coherer, he turned on an additional sensitive relay, which connected the winding of the electric bell to the battery with its contacts. So he created a kind of electromechanical current amplifier. In addition, he achieved even greater sensitivity from incoming devices to incoming EMCs by connecting a vertical mast antenna and making grounding.

Abroad and in Russia, modern skeptics doubting the depth and thoroughness of Popov's works claim that the technical solutions in his receivers were obvious after Lodge used the glass tube shaker — the clockwork. This can be partially agreed. Popov reacted positively to refusing to shake the coherer with his hands. But if Lodge had thought of shaking the tube with an electric bell hammer, then we may have now celebrated the anniversary of this particular event. Without detracting from the merits of the Lodge, we still say that he came up with what he managed.

The discovery was still made by A. S. Popov, but, we repeat, he also came up with a relay current amplifier, connected an antenna to the receiver, etc. The device turned out to be incredibly reliable, which was confirmed by serial copying by factories of many countries until 1910. And everywhere he was called the "Popov scheme."

"Co-author" of A. S. Popov on the discovery of radio by E. Branly in a letter published in the "Journal of the French Physical Society" in 1898, said: "Wireless telegraphy arose in reality from the experiments of Popov" [3, p. 49].

10 years later (in 1908), at the request of the RFHO commission on the contribution of A. S. Popov to the opening of the wireless telegraph, another "accomplice" O. Lodge said: "... I really used an automatic hammer or other shaker to restore the coherer's sensitivity, driven by a clockwork or some other mechanism, however, Popov for the first time achieved that the signal itself carried out the opposite effect. I believe that this is the innovation that we owe to Popov "[3, p. 257].

Outstanding Telegram

At the end of January 1896, under the conditions of Kotlin Island and the premises of the Kronstadt Branch of the Russian Technical Society, A. S. Popov conducted meter tests on meter waves for use at sea. The transmitter and receiver were connected to the same antennas in the form of symmetrical vibrators with metal square sheets at the ends. By agreement with the customer, he transmitted certain encoded messages [4].

March 24 (12), 1896 at the next scientific meeting of the Russian Chemical Society, held at St. Petersburg University, A. S. Povp together with his permanent assistant P. N. Rybkin (1864-1948) between the buildings of the educational institution (250 m) organized a two-word text message wireless transmission. The demonstration involved PPS in the UHF range with parabolic reflex antennas. The receiver was enclosed in a shielding box [5]. The meeting was attended by many famous Russian physicists, electrical engineers, administrative leaders of the army and navy. Here is how, in 1906, Hwolson, who was present at the reception hall, twice described the event: "The departure station was arranged in the chemical laboratory hall of St. Petersburg University, and the reception station in the conference room in the old physics room. Signs were transmitted by Morse code, whose key was in the chair of F.F. Petrushevsky. After each sign received, the chairman marked the corresponding letter on the board. It is difficult to describe the enthusiasm of those present when the words "HEINRICH HERTZ" appeared on the board [3, p. 94-97, p. 119-129]. Other testimonies of participants in the meeting can be found in [6].

Indirectly, the event is confirmed by the well-known Italian businessman for the introduction of radio G. Marconi (1874-1937). The autobiography History of My Life written under his dictation [7] to a large extent contains selected laudatory excerpts from popular newspapers and magazines reflecting his successes, but there is not a single telegram related to his seemingly memoirs "bravura" life. It can be assumed that he was unable to get ahead of Popov in sending a telegram over the air, and his pride and desire to maintain his status did not allow him to boast of dispatches written in pursuit of the first message.

Many authors of modern publications (mainly in Russia) express doubt about the event associated with the first telegram, biasedly read the speeches and works of A. S. Popov, believe that there is a lack of documents confirming the transmission of words. However, at the same time, all doubters and scholars trust the messages that Marconi threw three "points" of the letter S across the Atlantic Ocean on December 12, 1901. They never got acquainted with these documents about it, they think that "there", from which they draw information, - "all honestly." Meanwhile good zvestna and it hinted itself Marconi [7], which due to ignorance EMC propagation laws and imperfections in the atmosphere has not been received telegram equipment [8]. N. Tesla, being a major specialist in the transmission of EMC over long distances by 1901, did not believe in such an event. In doing so, he argued

Marconi deftly beat the setback: he invited engaged journalists to a press conference, who published enthusiastic publications about him, after which no one listened to serious specialists. As a result, the transatlantic operation for its organizer turned out to be a tangible benefit.

It should also be noted that A. S. Popov and G. Marconi never exchanged telegrams [9].

Sunrise Electronic Radio

In the history of technology, there are many examples of the development of scientific and technological achievements in two stages: first, in the primitive version, and then in the more advanced one. For example, people flew into the air first on balloons and airships, and only then on airplanes. For the first time shown by Bird 85 years ago (in 1924), electromechanical televisions were mass-produced and operated in many countries (and in Russia too) for almost 15 years. However, television based on a rotating disk with holes turned out to be a false start. It was replaced by electronic television, developed by a native of Russia V. Zvorykin (1889-1982).

Radio turned out to be the same situation. Much of what was built up in coherer equipment also turned out to be a false start. A ticket to the future was received by radios with semiconductor detectors and telephones for receiving signals by ear. And here A.S. Popov became the chief designer of the new technology.

In May 1899, P. Rybkin and D. Trotsky (1857-1918), assistants of A. S. Popov, discovered a detecting effect in the coherer. After which Popov developed a new receiver without a relay, but with headphones. After a short time, he also refused the coherer as an unreliable element and replaced it with a semiconductor diode developed by the German physicist K.F. Brown (1850-1918), the future Nobel Prize Laureate (1909) [10].

The new generation receivers turned out to be noticeably simpler, smaller, lighter and more reliable [11]. From the standpoint of modern times, it seems that creating them was even easier than coherer ones. However, in European and American centers this did not work. Moreover, at first they didn't even understand the importance of a semiconductor detector and for a long time they “invented” and introduced their own EMC rectifiers - mercury, liquid, magnetic, etc.

Literature

1. From the background of the radio. Collection of original articles and materials. Issue 1. Ed. L.I. Mandelstam.-M.-L .: publishing house of the ANSSSR, 1948. - http://lib.mexmat.ru/books/8553 .
2. Starikov V., Longinov A. Radio 90 years. - M .: publishing house "Knowledge", ser. “Radioelectronics and Communication”, 1985, No. 4. - http://www.amradio.ru/radioelbook/hystrory/art/_020.html.
3. A. S. Popov in the characteristics and memoirs of contemporaries.-M.-L.: Publishing House of the USSR Academy of Sciences, 1958.
4. Marchenkov V. The creative heritage of Alexander Stepanovich Popov. - http://rybkin.h16.ru/tvnasled.htm .
5. Mishenkov S. May 7 marks 110 years of radio and 60 years of Radio Day! - Radio, 2005, No. 5, 2nd p. reg., with. 4-6.
6. Kyandskaya-Popova E., Morozov I. On the question of the world's first radiogram. - http://fiz.1september.ru/2001/12/no12_ 01.htm .
7. Marconi G. The story of my life. - Marconi's Wireless Telegraph Co / The Bodleian library; University of Oxford archives.
8. Grigorov I. The Riddle of Marconi. - http://www.qrz.ru/articles/detail.phtml?id=141 .
9. Morozov I. A. S. Popov did not meet with G. Marconi and did not give him gifts. - http://fiz.1september.ru/2001/12/no16_2.htm .
10. Merkulov V. 60 years of the creation of the transistor. The beginning of the use of semiconductors . - Radio, 2007, No. 12, p. 7-9; 2008, No. 1, p. 5-7.
11. Pestrikov V. Receiver, survivor of the century. - http://www.qrz.ru/articles/article100.html .